

Technical Report 1230

The Perception and Estimation of Egocentric Distance in Real and Augmented Reality Environments

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May 2008



**United States Army Research Institute
for the Behavioral and Social Sciences**


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in Real and Augmented Reality Environments**

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FOREWORD

The U.S. Army has made a substantial commitment to the use of networked simulations for training, readiness, concept development, and test and evaluation. Augmented Reality (AR) technology, which has the capability to supplement information received directly from the actual environment with computer-generated information, has the potential to enhance both the conduct of military operation and training for those operations. However, the effectiveness of AR technology for either purpose has not been established.

This report describes an experiment in an ongoing program of research addressing the use of virtual environment and AR technology for training dismounted Soldiers. The findings from this research can be used to recommend AR characteristics and application methods that should be incorporated into future AR training and operational systems.

The U.S. Army Research Institute, Simulator Systems Research Unit, conducts research with the goal of providing information that will improve the effectiveness and efficiency of training simulators and simulations. The work described here is a part of ARI Research Task 233, VICTOR: Virtual Individual and Collective Training for Future Warriors

A handwritten signature in black ink, reading "Michele Sams". The signature is fluid and cursive, with the first name "Michele" and last name "Sams" clearly distinguishable.

MICHELE SAMS, Ph.D.
Director

THE PERCEPTION AND ESTIMATION OF EGOCENTRIC DISTANCE IN REAL AND AUGMENTED REALITY ENVIRONMENTS

EXECUTIVE SUMMARY

Research Requirement:

Previous research using verbal judgments of distance have shown that the distances tend to be underestimated. The extent to which distances are underestimated is greater with virtual environments than with real world environments. A primary focus of this study was to determine whether the judged distances to virtual objects in a real world environment produces results similar to those found previously for virtual objects in a virtual world.

Procedure:

Participants judged distances to a single object during two sets of twelve test trials. The objects were placed at varying distances. During one set, participants judged the distance to the real object while in the other set they judged the distance to a virtual representation of that object. Half of the participants provided their response verbally with a distance estimate in their unit of choice (i.e., feet or meters), and the other half provided their response by moving a remote controlled robot to the location of the previously viewed object.

Findings:

Participants who indicated their distance judgments to an object's perceived location by moving the robot were significantly more accurate than those who gave verbal estimates of the distances. Participants were significantly more accurate at judging the distance to real objects in a real environment than they were to virtual objects in an augmented environment. However, this latter effect was entirely due to females judging virtual objects much less accurately than they judged real objects. Males judged virtual objects as well as they judged real objects.

Utilization and Dissemination of Findings:

These results lend further support to the notion that estimated distance does not accurately represent perceived distance. Unless the task being performed specifically requires a numerical estimate of distance, it is recommended that methods similar to our distance replication method be used to accurately determine perceived distance.

THE PERCEPTION AND ESTIMATION OF EGOCENTRIC DISTANCE IN REAL AND AUGMENTED REALITY ENVIRONMENTS

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THE PERCEPTION AND ESTIMATION OF EGOCENTRIC DISTANCE IN REAL AND AUGMENTED REALITY ENVIRONMENTS

INTRODUCTION

Modern training programs incorporate technologies that have the potential to improve the effectiveness of training as well as increase safety. Virtual and augmented reality (AR) are two similar technologies that have shown great promise to improve training; however, computer generated stimuli might be perceived differently than real world stimuli. The goal of this research is to investigate human perception and performance in an environment in which the real world environment is augmented with virtual objects. The real world is modeled and tracked in relation to the user's head and body position so that the virtual objects may be overlaid onto the real world in their correct and desired positions. This is generally referred to as AR and the environment may be referred to as an augmented or mixed reality environment. AR is a new technology and as such, much of the early work in this area has concentrated on describing potential AR applications and overcoming the technical challenges such as accurate registration and tracking (Azuma, 1997). Researchers have only recently begun to investigate human perception and performance in augmented and mixed reality environments (Livingston, et al., 2004; Tang, Owen, Biocca & Mou, 2003; Azuma & Furmanski, 2003; Kirkley, 2003). These empirical studies are providing data on human interactions with AR technology that are essential for determining the usefulness of current AR for training and performance enhancement.

The Augmented Reality Performance Assessment Battery (ARPAB) was designed as a test battery to explore perception and performance in augmented environments. Previously, Kirkley (2003) had used the distance estimation task from this battery to explore distance estimation in an AR environment; results showed that participants' distance judgments were more accurate when the room was visible, when the object was on the ground vs. floating, and when the object was real vs. virtual. Distance estimation is important because many tasks require an individual to be able to perceive the location of an object accurately enough to be able to interact with it. Kirkley's work was unique by using AR to deliver real and virtual objects in a real environment, and interesting since it found significant results describing limitations of AR with distance presentation, but some shortcomings should be noted. For example, the head tracking system used by Kirkley produced significant drift in the virtual objects, which could have adversely affected his results. Kirkley's participants only viewed the objects with one eye, which possibly could also influence his results. In addition, Kirkley's tasks required judging four widely separated distances repeatedly under different conditions. Participants tested under various conditions could easily recall their previous estimates at each of the four distances and repeat these estimates regardless of the experimental condition presented. This could have decreased variability and produced better results for the AR condition than would have been obtained had more distances been used. Due to these issues we wanted to re-evaluate distance estimation in an AR environment using more discrete distances with smaller intervals between the distances, a better head tracker, and both eyes to make the distance judgments.

Distance Estimation - Verbal

In general, people tend to underestimate egocentric distance judgments, i.e., they perceive and report that the distance from them to some other object is shorter than what the distance truly

is. Studies consistently support this in real environments, especially when the egocentric distances are reported verbally (Gilinsky, 1951; Harway, 1963).

These difficulties in distance judgments generalize to immersive virtual environments as well. While immersed in a virtual environment, distance judgments from the location of the person's avatar to a virtual object are significantly underestimated when reported verbally (Witmer & Kline, 1998; Witmer & Sadowski, 1998; Henry & Furness, 1997; James & Caird, 1995; Lampton, Singer, McDonald, & Bliss, 1995). Are these distance judgment difficulties errors in the actual perception of the object's spatial location, or are they errors in the verbal reporting? More specifically, could people accurately interact with the object regardless of the inaccuracy of the number of feet or meters they assign to the distance?

Distance Estimation - Replication

Besides giving a verbal estimate of distance judgments, people can provide a distance judgment by replicating the distance in some way. Research shows that people can interact with the virtual objects at varying distances when tasks such as blindwalking are used (Thomson, 1983; Reiser et al., 1990; Loomis et al., 1992). Blindwalking involves the person closing their eyes after viewing a virtual object or location, and walking the distance they perceived to that spatial location. This direct interaction circumvents the inaccuracies of verbal distance judgments; however, the improvements made over verbal judgments might be mitigated when comparing both types of estimation methods in virtual environments. For example, other studies focusing on the importance of the environment type on the distance judgments show how distance estimation using either verbal judgments or direct interaction tasks is considerably shorter in the virtual world than in the real world (Lampton, Singer, McDonald, & Bliss, 1995; Witmer and Kline, 1998; Witmer and Sadowski, 1998).

The Present Experiment and Hypotheses

AR shows great promise as a training tool as well as a technology to aid task performance. There is much we need to learn about the effectiveness of AR. Not only do we need to know when AR can reasonably serve as a substitute for real environments, but the extent to which it can improve on what we can do in real environments, both as a performance enhancer and a training tool. AR research, especially research that addresses human performance in augmented environments is in its nascent period. There is much to be done and only a few research labs that have the necessary equipment and expertise to perform the work. A primary objective of this research was to compare the accuracy of distance judgments to virtual objects that augment a real environment (AR) with judgments to real objects in a real environment. A second major goal of this research was to determine if accuracy of distance judgments could be improved by allowing participants to indicate the distance to an object by maneuvering a robot to the perceived location of the object.

Previous research using verbal judgments of distance have shown the distances tend to be underestimated. The extent to which distances are underestimated is greater with virtual environments than with real world environments (Lampton, Singer, McDonald, & Bliss, 1995; Witmer & Kline, 1998). A primary focus of this experiment was to determine whether the judged distances to virtual objects in a real world environment produces results similar to those found previously for virtual objects in a virtual world. In this paper, we will describe the

perceptual and performance issues that were identified during research that utilized the ARPAB distance estimation test. These tests are relevant to potential applications of AR technology and will be used to identify and describe any perceptual and/or cognitive issues associated with judging distance to virtual objects that are overlaid onto a real world environment.

EXPERIMENTAL METHOD

The participants were 32 undergraduate and graduate students from the University of Central Florida. There were 18 females and 14 males, ranging in age from 18 to 51 years ($M = 24.66$, $SD = 8.1$). All participants had unaided or corrected 20/20 vision and had normal color vision. The participants were assigned randomly to the experimental conditions.

Experimental Design

The experiment used a $2 \times 2 \times 2 \times 2 \times 2 \times 12$ mixed model repeated measures design. The between-subject variables were object type (common or abstract objects), object size (small or large), environment order (augmented first or real first) and judgment method (verbal or replication). The within subjects variables included environment type (real and augmented) and distance (12 levels). Two random presentation orders for object distance were used, so that distances were neither presented in ascending or descending order. To control for gender effects or effects resulting from distance presentation order, gender and distance order were included as covariates.

Materials

The equipment used in this research included hardware and software for presenting virtual objects in an AR environment, a remotely controlled robot with the hardware and software for controlling it, and three questionnaires. Additional equipment included real objects and their virtual representations (Virtual Reality Markup Language [VRML] objects), a string of lights for calibration, a Strait-line laser tape measure for measuring distance to the robot, and eight 500-watt halogen spotlights for illuminating the real world objects. The objects included a soldier mannequin (167.6 x 50.8 x 21.6 cm), a computer monitor (43.2 x 41.9 x 42.5 cm), an adjustable office chair (105.4 x 59 x 50.8 cm), an office table (74.9 x 121.9 x 91.4 cm), a milk jug (25.4 x 15.2 x 15.2 cm), a small rectangular box (29.2 x 22.9 x 19 cm), a large rectangular box (144.8 x 68.6 x 50.8 cm), a small sphere (35.6 x 35.6 x 35.6 cm), and a large sphere (66 x 66 x 66 cm). The VRML virtual objects were displayed in the real environment in the same position and distance as the real objects and were designed to be perceived as approximately the same size as their real world counterparts (see Figures 1 and 2).

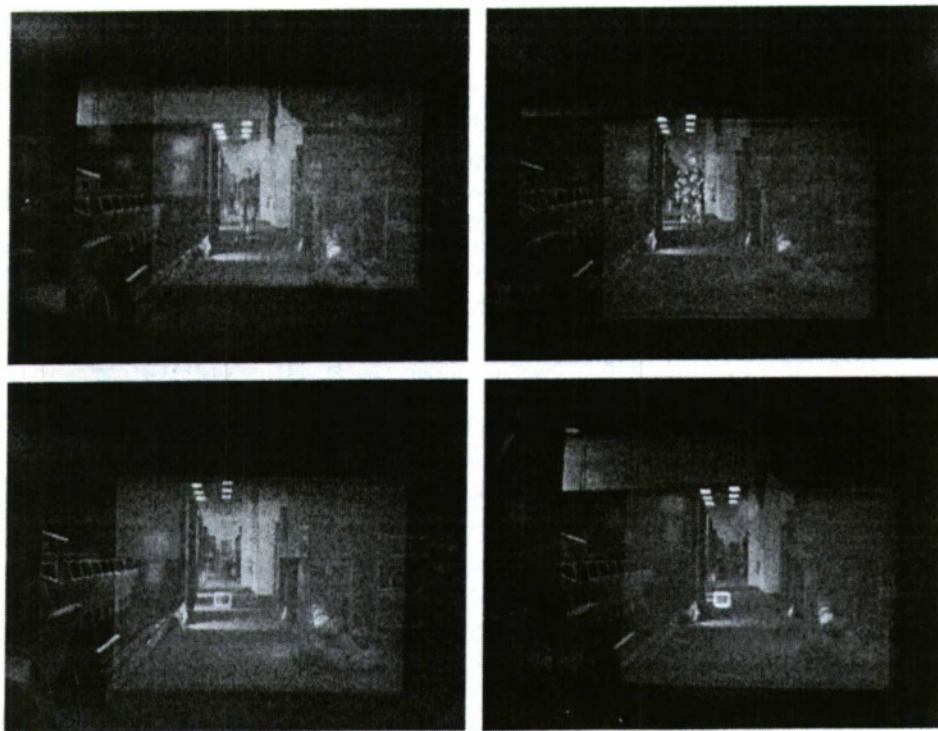


Figure 1. View through HMD of real (left column) & virtual familiar objects (right column).

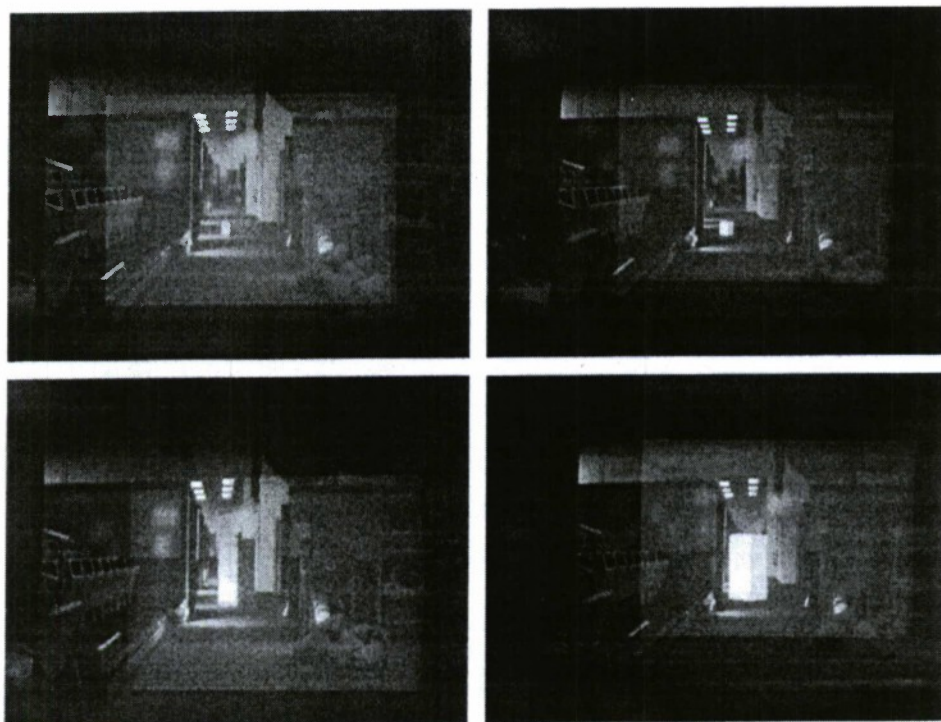


Figure 2. View through HMD of real (left column) & virtual abstract objects (right column).

AR hardware and software. A version of the Battlefield Augmented Reality System (BARS) was used in conjunction with ARPAB software to present virtual objects superimposed on the see-thru view of the real world environment. The BARS hardware included a laptop computer affixed to the upper torso of a mannequin and mounted on a cart for ease of use, a Sony Glasstron LDI-D100B stereo optical see-thru display for displaying high resolution virtual 3-D color objects, and the Intersense-900 tracking system for tracking user position and orientation (see Figure 3). The Glasstron display provided a 20-degree horizontal field-of-view of the virtual computer generated scene in each eye. The ARPAB software permitted the selection, ordering, and timing of object presentation, as well as the ability to record the distance judgments for each participant. The ARPAB software resided on Windows PC that was used to control the presentation of the experimental trials and capture the data.

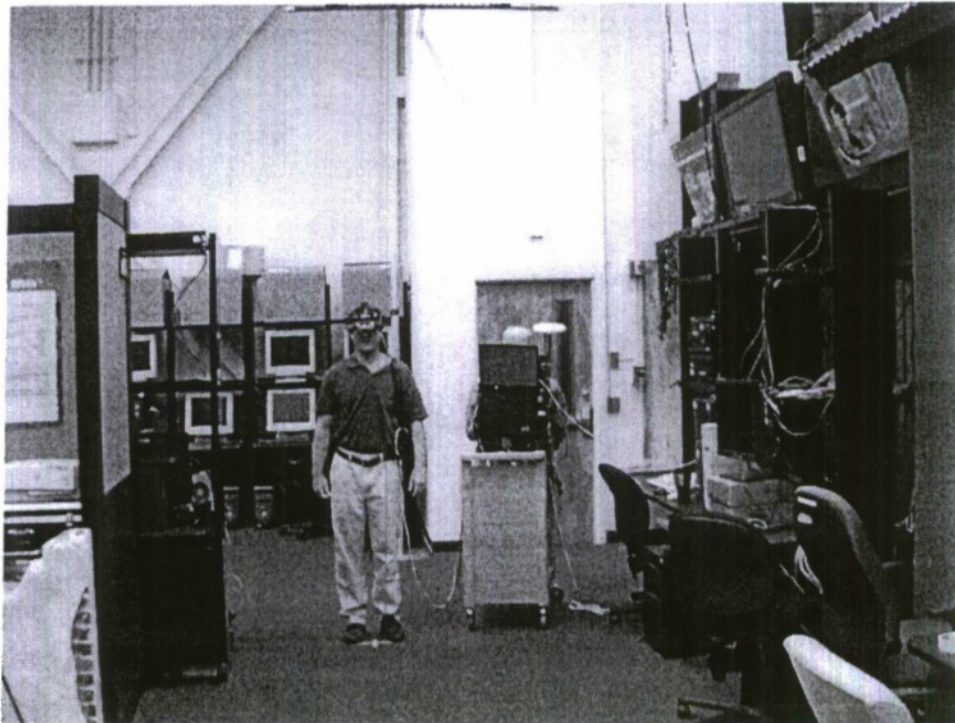


Figure 3. Battlefield augmented reality system (BARS) and Sony Glasstron HMD.

Remotely controlled robot hardware and software. A small remote-controlled vehicular style robot (see Figure 4) was used to allow participants to replicate the perceived distances to real and virtual target objects by moving the vehicle along a lighted corridor to the perceived object location. The robot was controlled remotely using an antenna and joystick control box. A second laptop was used for initializing the robot software, monitoring the robot power and other critical functions, as well as communicating direction and control.

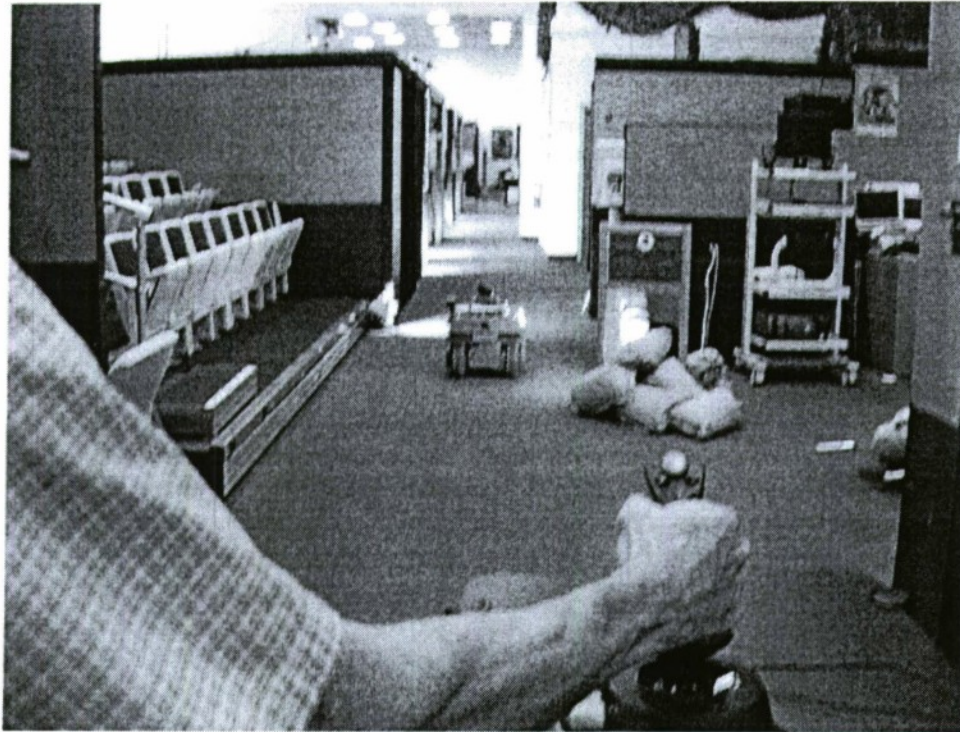


Figure 4. Controller and robot shown moving along the illuminated corridor.

Questionnaires. Three questionnaires were used – one for measuring presence, another for measuring comfort (simulator sickness), and a third for collecting participant demographic information and for identifying prior relevant experiences. The Presence Questionnaire (PQ) Version 4.0 (Witmer, Jerome, & Singer, 2005) included 33 items to determine the degree to which the participants reported a sense of presence in the AR Environment. The second questionnaire was a 16-item Simulator Sickness Questionnaire (SSQ) (Kennedy, Lane, Berbaum, & Lillienthal, 1993) to assess the amount of discomfort produced by the AR environment. The demographic questionnaire also contained 16 items.

Experimental Environment. The experiment was conducted in the SFC Paul Ray Smith Simulation and Training Technology Center in the Central Florida Research Park. The testing environment consisted of a long corridor that included numerous real world cues and landmarks. The testing area was artificially illuminated by overhead fluorescent lighting that provided adequate illumination for reading instructions or for easily viewing objects with the naked eye. Viewing real objects through the Glasstron, however, was much more difficult, especially at longer distances, and necessitated the use of spotlights. As much as possible, the spotlights were placed out of view along the edge of the corridor and strategically positioned to illuminate the real world objects. The spacing between adjacent spotlights was variable and typically the light provided by the lamp could be seen, but not the lamp itself. Because the lamps did not uniformly light the corridor, the spotlights from the lamps provided additional landmarks that participants could use, along with other landmarks in the environment, to remember object location. The spotlights were present when either real or virtual objects were presented.

Procedure

After consenting to participate, participants completed the demographic questionnaire and a baseline SSQ. They then entered the research laboratory where they read instructions describing the experimental task and ARPAB calibration procedures. Standing at the zero distance position, represented by crossmarks on the floor, participants placed the Glasstron on their head and positioned it for comfortable viewing. Participants also strapped the carrying case containing the Glasstron battery pack over their shoulder. The Glasstron was set for minimum opacity to yield the best view of the real environment. This opacity setting also provided a clear view of the virtual objects.

The participant's first task was to calibrate the ARPAB software so that the virtual objects were displayed in their correct locations. This was accomplished by first making the computer wireframe representation of the environment visible and having participants center the wireframe in their field-of-view to lock their view to the wireframe position, and then by asking participants to move their head to align the left back vertical edge of the wireframe with a string of lights placed in the corresponding real world position. Just prior to calibration, one researcher showed participants photographs of the wireframe correctly overlaid on the real world and explained the procedure in detail to ensure that the participants clearly understood the calibration procedures (see Appendix A). Because the calibration procedure was neither quick nor easy, participants were asked not to adjust the position of the Glasstron following calibration to avoid the need to recalibrate. After the calibration was completed, the wireframe was made invisible.

Following calibration, the participants received 6 practice trials to familiarize them with the experimental procedures and provide practice in judging distance to real and virtual objects. These trials also provided practice in controlling the movement of the robot for the distance replication group. A real object (a table 121.9 x 91.4 x 76.2 cm) was shown for three of the practice trials, while a 3-D virtual representation of the table was shown for the other three practice trials. The table was presented at distances of 1.5, 3.7, 5.8, 7.9, 10.1, 12.2 meters. During practice the participants did not receive any feedback on the accuracy of their distance judgments.

After completing the practice trials participants judged distances to a single object during two sets of twelve test trials. The objects were placed at distances of 1.5, 3.7, 5.8, 7.9, 10.1, 12.2, 14.3, 16.5, 18.6, 20.7, 22.9, and 25 meters. During one set, participants judged the distance to the real object while in the other set they judged the distance to a virtual representation of that object. Half of the participants judged the distance to the virtual object first while the other half judged the distance to the real object first.

The object presented to the participant was randomly selected from a set of 8 objects. Four of the objects were of relatively small size and four were substantially larger. Half of the objects were 3-D abstract shapes that can vary widely in size (large or small sphere, large or small rectangle) and half of the objects were familiar objects where the approximate size was known (adjustable office chair, life-size soldier mannequin, computer monitor, milk jug). This was done because knowledge of object size can potentially provide a cue to the object distance. Half of the participants received distance Order 1, while the other half received distance Order 2.

On each trial the following sequence of events occurred. Participants began each trial with their eyes closed. When the object was presented, participants opened their eyes and

viewed the object for 12 seconds. Participants then closed their eyes and the object was removed. Participants opened their eyes and rendered their distance judgment. Participants in the estimation group verbally reported the distance in their preferred units (feet or meters), while participants in the replication group maneuvered a robot to the location where they judged the previously displayed object to have been positioned. Participants closed their eyes while their distance judgment was recorded. The object was then repositioned in preparation for the next trial. For the replication group, the robot was returned to a position just forward of the participant. Participants opened their eyes after this repositioning to make their next judgment.

After completing their last trial, participants completed another SSQ and the PQ. They were then assigned pay or class credit for their participation and received a short written debrief.

RESULTS

A primary objective of this research was to compare the accuracy of distance judgments to virtual objects that augment a real environment (augmented reality) with judgments to real objects in a real environment. A second major goal of this research was to determine if accuracy of distance judgments could be improved by allowing participants to indicate the distance to an object by maneuvering a robot to the perceived location of the object.

We selected signed error as our basic index of the accuracy of distance judgments. Signed error is defined as the judged distance minus the true distance to the target. Because the error in distance judgments is often proportional to the distance of the target from the observer (Witmer & Kline, 1998), we chose to report signed relative error rather than the more basic signed error. Signed relative error is defined as the signed error divided by the true target distance. Figure 5 summarizes the distance judgment results for the two environment types (augmented and real) and two judgment types (estimation and replication). For exposition purposes signed relative error is shown in Figure 5 as a percentage of the true target distance. The figure indicates decreased performance when the verbal estimation method was used and when the real environment was augmented with virtual objects.

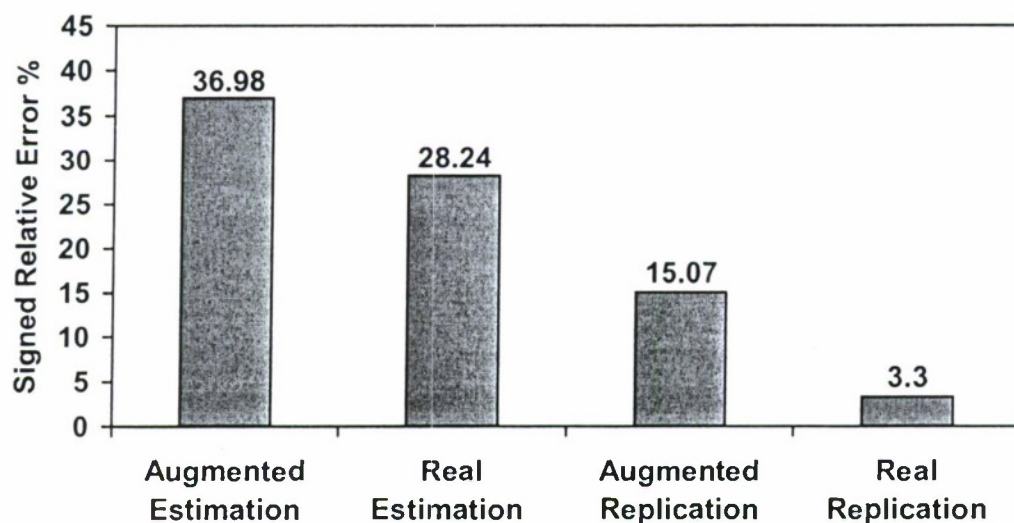


Figure 5. Distance judgment accuracy by environment type and judgment type.

The results illustrated in Figure 5 are supported by the mixed model repeated measures analysis. Participants who indicated their distance judgments to an object's perceived location by moving the robot were significantly more accurate than those who gave verbal estimates of the distances, $F(1,14) = 25.35, p < .001$. Participants were significantly more accurate at judging the distance to real objects in a real environment than they were to virtual objects in an augmented environment, $F(1,14) = 33.85, p < .001$. However, this latter effect was entirely due to females judging virtual objects much less accurately than they judged real objects. Males judged virtual objects as well as they judged real objects. The significant gender by environment type interaction, $F(1,14) = 18.35, p < .001$, is shown in Figure 6.

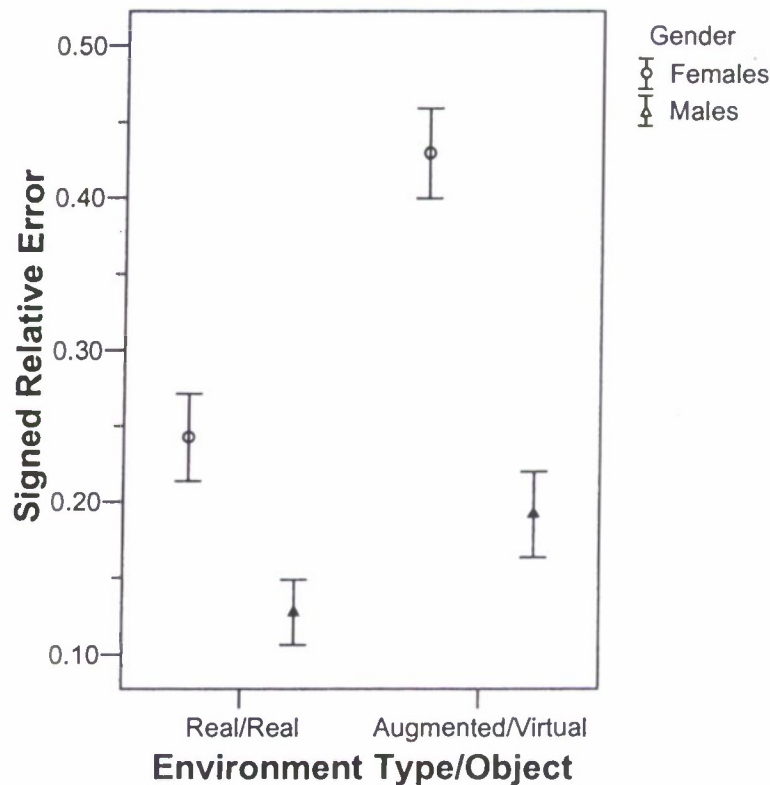


Figure 6. Differential gender effects on distance judgment accuracy to real and virtual objects.

No other main effects, including object distance had significant effects on signed relative error. However the interaction between distance and distance order was significant, $F(1,14) = 8.4, p < .05$, suggesting that distance at which the object was viewed significantly affected relative error for distance order 1, but not for distance order 2. The 3-way interaction between distance by distance order by object size was significant as well, $F(1, 14) = 9.12, p < .05$. Distance order also interacted with the environment type, having more effect on virtual objects in an augmented reality environment than on real objects in a real environment, $F(1,14) = 15.03, p < .01$. None of the interactions with distance order were of particular interest and it is likely that some of these effects are spurious.

Environment order interacted significantly with environment type, $F(1,14) = 4.89, p < .05$. The amount of error in judging the distance to virtual objects was significantly reduced

when preceded by distance judgments of real objects (see Figure 4). Hence previous experience in judging distance to the real objects improves subsequent judgments of the virtual representations of those objects. There were two significant 3-way interactions involving environment type. The environment type by environment order by object size interaction was significant, $F(1, 14) = 8.74, p < .01$. The environment type by judgment type by object type interaction was also significant, $F(1, 14) = 8.219, p < .05$. Except for the real-world representations of the abstract objects, participants always were more accurate for real objects than for virtual objects in an augmented environment. There was also a significant four-way interaction, environment type by environment order by object type by judgment type that could not be interpreted.

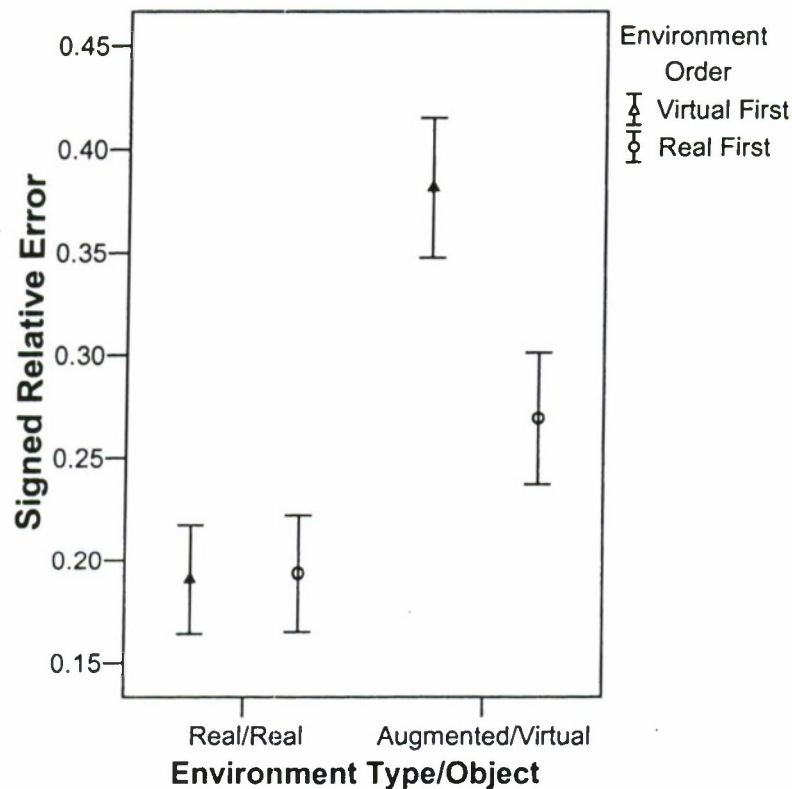


Figure 7. Presentation order effects on distance judgment accuracy.

As this was our first research project using AR, we administered the presence and SSQ to assess presence and simulator sickness in an AR environment. The PQ results suggest that participants experienced significant presence ($M = 120.62, SD = 28.33$). Responses to individual PQ items suggest that the participants adjusted quickly to the augmented environment and reported that the visual and control interfaces did not interfere with task performance. Surprisingly, the SSQ simulator sickness scores were slightly high ($M = 31.44, SD = 39.26$). We did not anticipate much sickness because the participants were stationary with little head movement and the objects being judged also did not move. Despite this, one participant (SSQ = 104.72) reported nausea and a slight headache (both symptoms of simulator sickness). This participant also reported a history of migraine headaches with tunnel vision and dizziness. The

higher scores were most likely due to the extended exposure time to the AR environment. The sessions lasted approximately 45 minutes.

DISCUSSION

The significant main effect of environment type in this research indicates that participants underestimate the distance to virtual objects in a real environment more than they do for real objects in a real environment. However, further analyses of the data revealed that this was only true for our female participants. It is not clear what is responsible for this apparent gender-specific effect. Differences in spatial ability between our male and female participants is a possible explanation, but why would spatial ability differences affect judgments to virtual objects to a greater degree than it affects judgments to real objects? Perhaps, judging the position of virtual objects in the real world may require superior spatial visualization skills, since the virtual objects are less likely than real objects to appear to be clearly anchored to a position on the floor. Hence participants rely on visualization skills to accurately determine the position where a virtual object intersects the floor. Studies examining spatial visualization skills in men and women have generally shown men to have better visualization skills (Eisenberg & McGinty, 1977; McGee, 1979; Linn & Petersen, 1986; Battista, 1990). A difference in visualization skills between our men and women participants, assuming they exist, might explain our otherwise puzzling results.

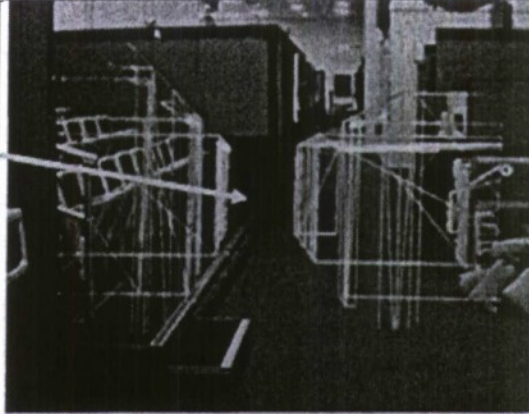
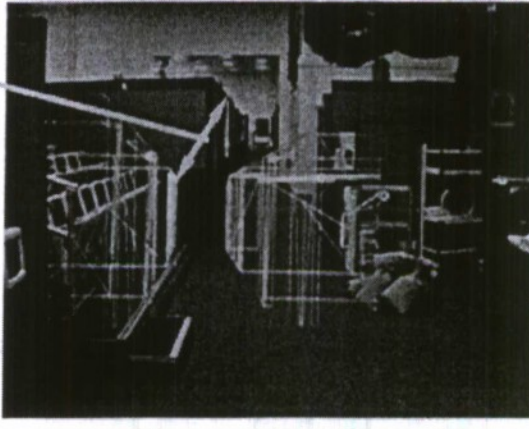
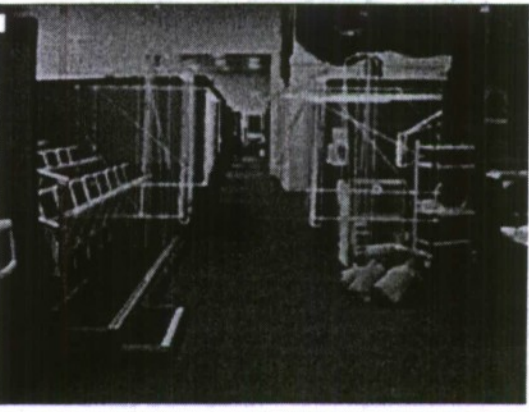
The method used to obtain distance judgments can have a dramatic effect on the accuracy of those judgments (Thomson, 1983; Elliot, 1987; Rieser, Ashmead, Talor, & Youngquist, 1990; Witmer & Sadowski, 1998). In the current experiment, asking participants to replicate the perceived distance by moving a robot to the perceived location produced more accurate distance judgments than did the verbal distance estimation procedure. This finding suggests that the verbal estimates of distance by untrained participants may not accurately reflect perceived distances. The accuracy of distance judgments is clearly improved by using the distance replication procedure to obtain the judgments (see Figure 5). Furthermore, the results shown in Figure 5 suggest that the effects of distance judgment method were greater than were the effects of environment type. The magnitude of the distance judgment error was considerably larger for the estimation condition in the real environment than it was for the replication condition in the augmented environment. These results lend further support to the notion that estimated distance does not accurately represent perceived distance. Unless the task being performed specifically requires a numerical estimate of distance, it is recommended that methods similar to our distance replication method be used to accurately determine perceived distance.

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APPENDIX A: CALIBRATION INSTRUCTIONS

<ol style="list-style-type: none">1. Focus on the virtual wireframe of the hallway, specifically try to keep in the center of the display the location where all the virtual walls converge.2. When you have the wireframe centered, please inform the experimenter so he can lock the wireframe in place.	
<ol style="list-style-type: none">3. Notice the real world walls are not aligned with the wireframe.	
<ol style="list-style-type: none">4. Once the wireframe is locked in the center of the display, you may move your head to align the real world walls with the wireframe walls. Please line up the very end of the wall on the left hand side with the lights hanging half way down the hall.5. When you have aligned them as best you can, inform the experimenter so he can lock the wireframe walls onto the real world walls.	

APPENDIX B: SIMULATOR SICKNESS QUESTIONNAIRE

Simulator Sickness Questionnaire (SSQ)
Kennedy, Lane, Berbaum, and Lillenthal (1993)

Keyboard Directions: Position the cursor over the response that you want to select for a given question, then click the left mouse button to select it. Use the scroll bar or PgDn button to move to the next set of (off-screen) questions. Please tell the experimenter when you are finished.

Instructions: Please indicate the severity of symptoms that apply to you

1. General Discomfort	None	Slight	Moderate	Severe
2. Fatigue	None	Slight	Moderate	Severe
3. Headache	None	Slight	Moderate	Severe
4. Eye Strain	None	Slight	Moderate	Severe
5. Difficulty Focusing	None	Slight	Moderate	Severe
6. Increased Salivation	None	Slight	Moderate	Severe
7. Sweating	None	Slight	Moderate	Severe
8. Nausea	None	Slight	Moderate	Severe
9. Difficulty Concentrating	None	Slight	Moderate	Severe
10. Fullness of Head	None	Slight	Moderate	Severe
11. Blurred Vision	None	Slight	Moderate	Severe
12. Dizzy (Eyes Open)	None	Slight	Moderate	Severe
13. Dizzy (Eyes Closed)	None	Slight	Moderate	Severe
14. Vertigo*	None	Slight	Moderate	Severe
15. Stomach Awareness	None	Slight	Moderate	Severe
16. Burping	None	Slight	Moderate	Severe

*Vertigo is a disordered state in which the person or his/her surroundings seem to whirl dizzily: giddiness.

APPENDIX C: PRESENCE QUESTIONNAIRE

PRESENCE QUESTIONNAIRE (Witmer & Singer, Vs. 3.0, Nov. 1994)

Characterize your experience in the environment, by marking an "X" in the appropriate box of the 7-point scale, in accordance with the question content and descriptive labels. Please consider the entire scale when making your responses, as the intermediate levels may apply. Answer the questions independently in the order that they appear. Do not skip questions or return to a previous question to change your answer.

WITH REGARD TO THE EXPERIENCED ENVIRONMENT

1. How much were you able to control events?

NOT AT ALL			SOMEWHAT			COMPLETELY

2. How responsive was the environment to actions that you initiated (or performed)?

NOT RESPONSIVE			MODERATELY RESPONSIVE			COMPLETELY RESPONSIVE

3. How natural did your interactions with the environment seem?

EXTREMELY ARTIFICIAL			BORDERLINE			COMPLETELY NATURAL

4. How much did the visual aspects of the environment involve you?

NOT AT ALL			SOMEWHAT			COMPLETELY

5. How much did the auditory aspects of the environment involve you?

NOT AT ALL			SOMEWHAT			COMPLETELY

6. How natural was the mechanism which controlled movement through the environment?

EXTREMELY			BORDERLINE			COMPLETELY
ARTIFICIAL						NATURAL

7. How compelling was your sense of objects moving through space?

NOT AT ALL			MODERATELY			VERY
			COMPELLING			COMPELLING

8. How much did your experiences in the virtual environment seem consistent with your real world experiences?

NOT			MODERATELY			VERY
CONSISTENT			CONSISTENT			CONSISTENT

9. Were you able to anticipate what would happen next in response to the actions that you performed?

NOT AT ALL			SOMEWHAT			COMPLETELY

10. How completely were you able to actively survey or search the environment using vision?

NOT AT ALL			SOMEWHAT			COMPLETELY

11. How well could you identify sounds?

NOT AT ALL			SOMEWHAT			COMPLETELY

12. How well could you localize sounds?

NOT AT ALL			SOMEWHAT			COMPLETELY

13. How well could you actively survey or search the virtual environment using touch?

NOT AT ALL			SOMEWHAT			COMPLETELY

14. How compelling was your sense of moving around inside the virtual environment?

NOT			MODERATELY			VERY
COMPELLING			COMPELLING			COMPELLING

15. How closely were you able to examine objects?

NOT AT ALL			PRETTY			VERY
			CLOSELY			CLOSELY

16. How well could you examine objects from multiple viewpoints?

NOT AT ALL			SOMEWHAT			EXTENSIVELY

17. How well could you move or manipulate objects in the virtual environment?

NOT AT ALL			SOMEWHAT			EXTENSIVELY

18. How involved were you in the virtual environment experience?

NOT			MILDLY			COMPLETELY
INVOLVED			INVOLVED			ENGROSSED

19. How much delay did you experience between your actions and expected outcomes?

NO DELAYS			MODERATE			LONG
			DELAYS			DELAYS

20. How quickly did you adjust to the virtual environment experience?

NOT AT ALL			SLOWLY			LESS THAN
						ONE MINUTE

21. How proficient in moving and interacting with the virtual environment did you feel at the end of the experience?

NOT			REASONABLY			VERY
PROFICIENT			PROFICIENT			PROFICIENT

22. How much did the visual display quality interfere or distract you from performing assigned tasks or required activities?

NOT AT ALL			INTERFERED			PREVENTED
			SOMEWHAT			TASK PERFORMANCE

23. How much did the control devices interfere with the performance of assigned tasks or with other activities?

NOT AT ALL			INTERFERED			INTERFERED
			SOMEWHAT			GREATLY

24. How well could you concentrate on the assigned tasks or required activities rather than on the mechanisms used to perform those tasks or activities?

NOT AT ALL			SOMEWHAT			COMPLETELY

25. How completely were your senses engaged in this experience?

NOT			MILDLY			COMPLETELY
ENGAGED			ENGAGED			ENGAGED

26. To what extent did events occurring outside the virtual environment distract from your experience in the virtual environment?

NOT AT ALL			MODERATELY			VERY MUCH

27. Overall, how much did you focus on using the display and control devices instead of the virtual experience and experimental tasks?

NOT AT ALL			SOMEWHAT			VERY MUCH

28. Were you involved in the experimental task to the extent that you lost track of time?

